Rapid Spectrophotometric Changes in R127 and Reversal of the Decline

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R127, the famous Luminous Blue Variable in the Large Magellanic Cloud, was found in the peculiar early-B state and fainter during January 2008, suggesting that the major outburst which started sometime between 1978 and 1980 was drawing to a close, and that the star would presumably continue to fade and move toward earlier spectral types until reaching its quiescent Ofpe/WN9 state. Archival data showed that the main spectral transformation from the peculiar A-type state at maximum started between 2005 and 2007, and that it was in close concordance with features in the light curve. However, subsequent observations during 2008 and early 2009 have shown that the spectrum of R127 is now returning to a cooler, lower excitation state, while the photometry shows a new brightening of the star. Here, we present the time variation of selected spectral regions, along with the accompanying light curve evolution. A speculative 7-year cycle during the decline bears further investigation. The curious behavior of R127 provides an opportunity to gain further insight into the rapid transitional stages in the late evolution of very massive stars.

Introduction

The luminous blue variables (LBVs) are very massive stars which transit through a highly unstable phase, during which they suffer succesive violent outbursts, losing enough mass to eventually become classical WR stars. Eta Carinae, the prototype of the LBV class and its most famous member, has ejected at least 12 $M_\odot$ during its spectacular 19th century eruption which gave rise to the Homunculus nebula (Smith 2008). LBVs are located in the H-R diagram just to the left of the Humphreys-Davidson limit (Humphreys & Davidson 1994, and references therein) beyond which no stars are observed; thus they probably experience an instability which prevents further redward evolution. The mechanism responsible for the LBV eruptions is not completely understood, but it is most probably related to the Eddington limit (Humphreys & Davidson 1994, Smith & Owocki 2006).

Radcliffe (R)127 (Feast et al. 1960) = HDE 269858 = Sk -69 220 is located in a compact subgroup of NGC 2055, a small evolved LMC cluster which harbors several mid-O and early-B supergiants (Walborn 1991, Heydari-Malayeri et al. 2003). It is south of 30 Dor and not far from SN 1987A. R127 was first classified as O Iafpe by Walborn (1977, based on an observation from Dec. 1975), and then reclassified as Ofpe/WN9 by Walborn (1982, echelle observation from Nov. 1978).

In 1982, R127 was discovered to have entered a classical LBV outburst (Stahl et al. 1983, Walborn 1983) and the original Ofpe/WN9 spectral type was thus assumed to represent the quiescent LBV state. During this large outburst R127 became the brightest star in the LMC, first displaying a peculiar early-B type spectrum, which subsequently evolved -with fluctuations- into late-B (Stahl & Wolf 1986), until reaching a peculiar A-type spectrum, dominated by Fe II and Ti II, which remained until at least 2002 (Walborn et al. 2008).

In early 2008, R127 was found at a peculiar early-B type, while subsequent photometric observations showed it was also considerably fainter. This was interpreted as the final decline from the 30 year outburst (Walborn et al. 2008) which would continue until reaching the quiescent Ofpe/WN9 state. Archival data showed the transition had begun sometime between 2005 and 2007.

Contrary to those expectations, subsequent observations demonstrated that R127 has reversed the decline, entering a steep brightening phase matched by a new cooling of its spectrum, as explained in the following sections.

New Observations

18 new V-band images were obtained at LCO with the Swope telescope plus CCD detector, same setup as reported in Walborn et al. (2008).

12 new high resolution spectroscopic observations were performed with the echelle spectrographs available at the 2-m class telescopes at CASLEO, LCO and La Silla during different observing runs ending in May 2009 (details of the instrumental configurations are also found in Walborn et al. 2008).

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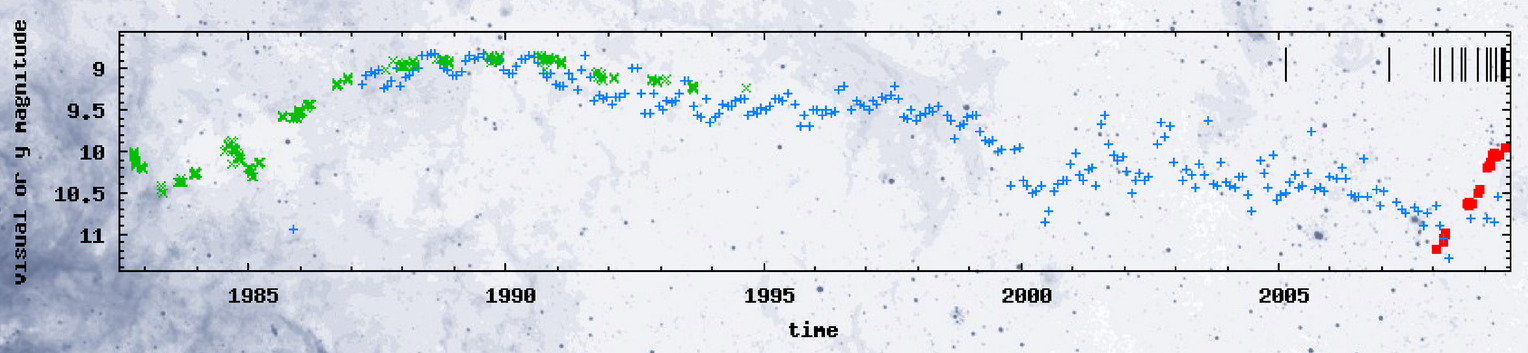
Results

After what seemed to be the end of the LBV outburst that began in 1982, as announced by Walborn et al. (2008), follow-up observations later in 2008 and during 2009 showed that R127, after reaching a minimum in early 2008, reversed the decline, evolving to brighter magnitudes and cooler spectral types.

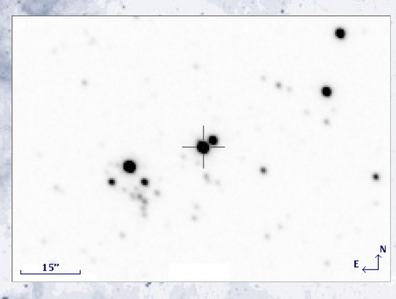
Our last spectrum resembles (though corresponding to a somewhat cooler spectral type) the 'transitional' spectrum of February 2005.

The light curve appears to display a broad undulation of unknown origin on a timescale of about 7 years; a search for binary phenomena is worth undertaking. The current rebrightening is consistent with that pattern. There also appear to be shorter timescale events about yearly at some points in the lightcurve.

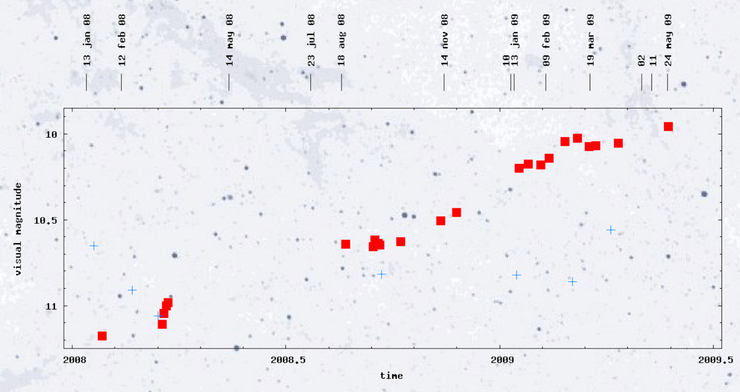
We plan to resume photometric and spectroscopic observations of this fascinating target later this year, as soon as the LMC becomes observable.



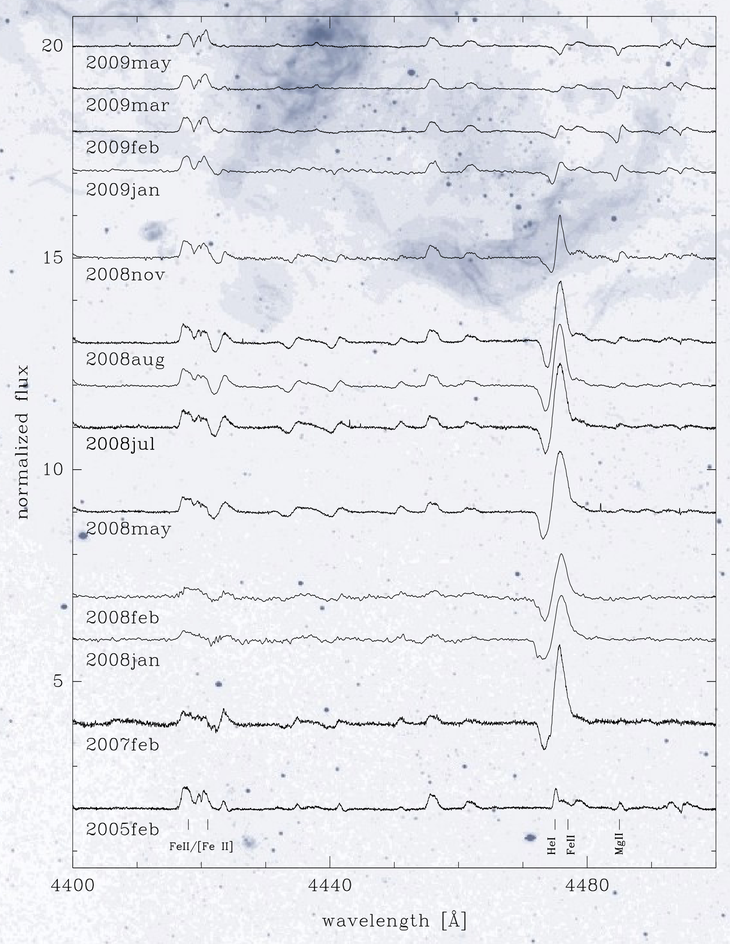
Lightcurve of R127. Green symbols represent the photometric measurements in Stroemgren y (Sterken et al. 1994), the blue crosses are the filtered monthly average values of the visual estimates from the AAVSO database, and the red squares depict the Johnson V magnitudes observed from LCO. The epochs of recent spectroscopic observations are indicated by ticks. It is remarkable, how R127 is brightening since January 2008.

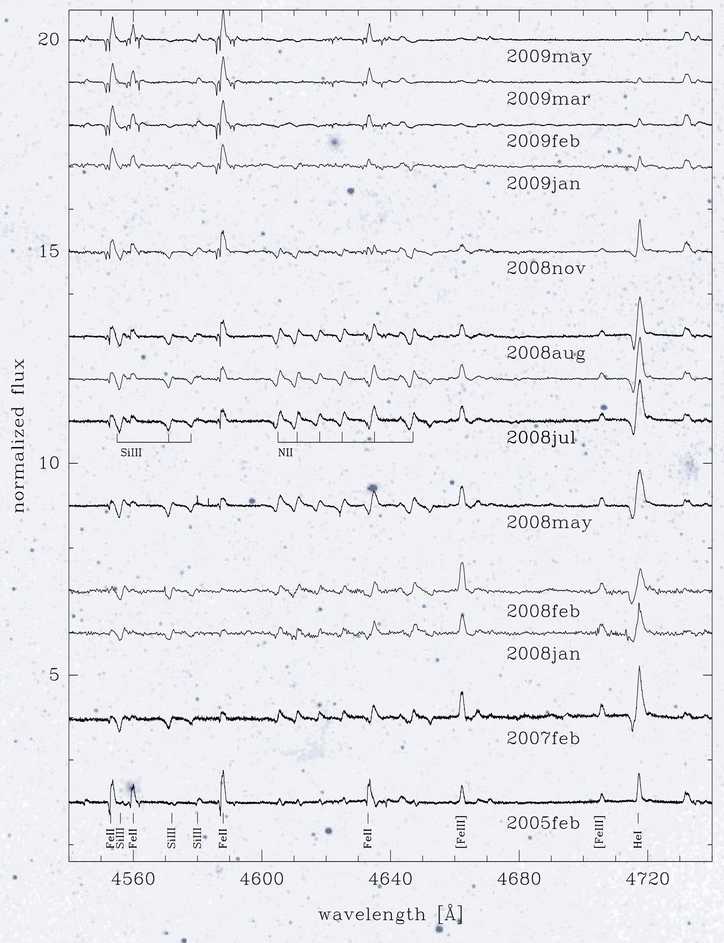


V-band image of R127 obtained on March 19, 2008 at Swope (LCO).



Detail of the light curve zooming on the 2008-2009.5 period.





Time sequence showing two different wavelength regions from rectified echelle spectra of R127, covering the decline from the outburst and its recent reversal (observing times are indicated in the lightcurve figure).

Left: The remarkable behavior of the 4414-17 Å complex with time is caused by the variation in the contribution of [Fe II] relative to Fe II at nearly the same wavelengths. The first arises farther out in the wind where the velocity is higher. Note also the transition from Fe II λ4473 to He I λ4471, and Mg II λ4481 absorption; and how the 2007-2008 spectra are dominated by the strong He I λ4471 P Cygni profile, which then gradually weakens until turning into (pure?) absorption by May 2009.

Right: Here, we see that the P Cygni profile of He I λ4713; the B-type features, such as Si III $\lambda\lambda$4552, 4568, 4575 and N II $\lambda\lambda$4601, 4607, 4614, 4621, 4631, 4643; as well as [Fe III] $\lambda\lambda$4658, 4701.5, after being prominent in the 2007-2008 spectra, become weaker until disappearing in May 2009, while the Fe II lines grow stronger, developing double narrow absoption features in some of their P Cygni profiles.